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Extended-spectrum beta-lactamase and ampicillin Class C beta-lactamase-producing *Escherichia coli* from food animals: A review

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Abstract

Antimicrobial resistance has gained global notoriety due to its public health concern, the emergence of multiple drug-resistant bacteria, and lack of new antimicrobials. Extended-spectrum beta-lactamase (ESBL)/ampicillin Class C (AmpC)-producing *Escherichia coli* and other zoonotic pathogens can be transmitted to humans from animals either through the food chain, direct contact or contamination of shared environments. There is a surge in the rate of resistance to medically important antibiotics such as carbapenem, ESBL, aminoglycosides, and fluoroquinolones among bacteria of zoonotic importance. Factors that may facilitate the occurrence, persistence and dissemination of ESBL/AmpC-Producing *E. coli* in humans and animal includes; 1). oral administration of antimicrobials to humans primarily (by physician and health care providers) and secondarily to animals, 2). importation of parent stock and day-old chickens, 3). farm management practice and lack of water acidification in poultry, 4). contamination of feed, water and environment, 5). contamination of plants with feces of animals. Understanding these key factors will help reduce the level of resistance, thereby boosting the therapeutic effectiveness of antimicrobial agents in the treatment of animal and human infections. This review highlights the occurrence, risk factors, and public health importance of ESBL/AmpC-beta-lactamase producing *E. coli* isolated from livestock.

Keywords: antimicrobial resistance, *Escherichia coli*, extended-spectrum beta-lactamase/ampicillin Class C.

Introduction

Antimicrobial resistance (AMR) in food animals is a global emergency. The global spread and dissemination of extended-spectrum beta-lactamase (ESBL)-producing *Escherichia coli* posed a significant threat to the efficacy of antimicrobial agents, particularly the third- and fourth-generation cephalosporins [1-5]. The common contributing factors to the development of AMR in bacteria are sustained and indiscriminate use of antimicrobials in food animal production and in the treatment of life-threatening illnesses [6]. This has led to the emergence and widespread dissemination of CTX-M group enzymes first in the environment and then to humans and a variety of food-producing animals including pigs, cattle, and chickens [6-10]. Hence, serving as important loci for the transmission of highly resistant bacterial zoonotic pathogens [4,11,12].

ESBLs enzymes act by inactivating beta-lactams antibiotics such as penicillin and third generation cephalosporins through hydrolysis of their beta-lactam ring. The enzymes are found majorly in *Enterobacteriaceae* a normal gut flora. The frequently encountered ESBLs are the CTX-M, which were first identified in Germany, France, and South America.

Over the years, the CTX-M type enzymes that have gained global notoriety are the $bla_{\text{CTX-M-15}}$ and $bla_{\text{CTX-M-14}}$. Since then, the prevalence of these enzymes has skyrocketed and become a major problem in health care settings. This was partly due to limited treatment options and prolonged hospital admission. Increased utilization of the last resort antibiotics such as colistin and carbapenems has also led to the emergence of *E. coli* strain resistant to carbapenem and colistin. This then creates a huge health problem in economically less developed countries, where a lack of good sanitation favors the transfer and dissemination of AMR genes between animals, human, and the environment [13-19].

This review highlights the occurrence, risk factors, and public health importance of ESBL/ampicillin Class C (AmpC)-beta-lactamase producing *E. coli* isolated from food animals.

Antimicrobial Use in Animals and the Burden of Resistance Transfer to Human

The use of oral antimicrobial agents in animals either for prophylaxis or treatment of gastrointestinal (GI) tract infection has contributed immensely to the development and sustenance of resistance and in the emergence of resistant pathogens. Oral administration of certain antimicrobial agents is accompanied by poor absorption and bioavailability in the GI tract. Thus, creating a situation whereby resistance determinants, resistant bacteria, and other by-products of the drug are excreted through feces and then contaminate the environment. This constitutes a serious public health problem in areas where animal feces are used as organic manure to grow vegetables [13,20].

Antimicrobial use in food animals leads to selective pressure, which facilitates the propagation in animal resistant bacteria initially isolated from humans. Several studies have reported the occurrence of CTX-M variant colonizing the gut of mammals, farmed birds, and raw meat [21-25]. Evidence of transmission of ESBL/AmpC producing *E. coli* between animals and humans has been reported. The acquisition of plasmid-mediated bla_{CTX-M} by *E. coli* strains of animal origin from humans in the United Kingdom has also reported [26-28]. The dissemination of plasmid in epidemic proportion from animals to humans has been observed in China, the United Kingdom, and the Netherlands [21,27,28]. Horizontal transfer of plasmid and other resistance determinants is the major contributor of AMR transmission from humans and animals than the clonal spread of the bacteria itself. Plasmids in genetically diverse animals and human strains revealed a high level of similarity. The lack of regulation of wet food markets in some developing countries contributed significantly to the dissemination of bla_{CTX-M} from animals to humans through the food chain and from animals to the environment through contact with live animal or animal products [29,30]. Wet food markets retail a variety of food and allow unsafe handling of food. This creates a favorable environment for the propagation and dissemination of resistance determinants and resistant bacteria from animals to humans. The above scenario is more likely to be seen in countries such as China and India, where there is a high number of wet food markets and high human population. For example, CTX-M-55 is now the most frequently identified bla_{CTX-M} genotypes both in animals and humans in China. Interestingly, Zhang *et al*. [31] opined that it might have arisen from food animal sources. The use of antibiotics in food animal has been projected to increase to 67% by the year 2030; thus, food animals as likely reservoirs of resistance determinants will gain global interest [14,32,33].

ESBL-Producing *E. coli* in Livestock and its Public Health Importance

Over the years, there is an increased fear that the emergence and dissemination of ESBL/AmpC-producing *Enterobacteriaceae* in animals may have a negative impact on human health. The transmission of these pathogens between humans and animals is facilitated by several complex interrelated factors. The location of these genes on a mobile genetic element is thought to favor the widespread dissemination of these pathogens. Evidences of shared reservoirs of clones, ESBL/AmpC genes, and plasmids, suggesting the possibility of coselection of resistance have also been reported [27].

The occurrence of ESBL/AmpC enzymes between humans and animals differs significantly, thus, leading to underestimating the actual magnitude of their transfer. It is important to note that, while several combinations of plasmids and ESBL/AmpC genes tend to record more epidemiological success than others, they differ between humans and animals. Members of the *Enterobacteriaceae* family, particularly *E. coli* tends to play a pivotal role in the clonal dissemination of ESBL/AmpC genes. *E. coli* strain ST131 has been reported to serve as a major contributor to human infection and high producer of CTX-M-15 ESBL type [34-36].

The isolation of ESBL/AmpC-producing *E. coli* from animals that are related to those obtained from humans has been reported. van Hall *et al*. [37] reported that 19% of ESBL-producing *E. coli* isolated from humans were related to those obtained from chicken meat, and 39% of ESBL-producing *E. coli* isolated from chickens' meat share the same clonal lineage as those obtained from humans, hence, indicating widespread clonal dissemination of the pathogens. Other studies also reported the roles of similar plasmids IncI1/ST3 facilitating the spread of $bla_{CTX-M-1}$ in unrelated food animals and humans. Madec *et al*. [38] reported the occurrence of IncI1/ST3 plasmids in 83% of CTX-M-1-producing *E. coli* from humans that share identical restriction patterns as those obtained from animals. The occurrence of indistinguishable plasmids that carried the $bla_{CTX-M-1}$ from personnel working in pig farm, pigs, and manure has also been reported [39].

The occurrence of ESBL-producing *E. coli* as the causative agents of many diseases in animals is a common finding in veterinary medicine. Many studies have reported the occurrence of ESBL-producing *E. coli* in livestock and companion animals. *E. coli* developed resistance to extended-spectrum cephalosporins through the acquisition of conjugative plasmids carrying genes that codes for ESBL or AmpC beta-lactamase [40,41]. A feat, that facilitates the global dissemination of ESBL genes from one bacterial strain to another in Europe, the most commonly identified ESBL type enzyme associated with livestock is

the CTX-M-1. The impact of the zoonotic transfer of these pathogens to humans in close contact with animals is still being studied. However, several studies have reported the transfer of ESBL genes and ESBL-producing *E. coli* from livestock to farm personnel. Nonetheless, other routes of transmission such as consumption of contaminated pork, beef, milk, and chickens have also been implicated as potential risk factors of human infection or colonization. It is important to note that, the occurrence of ESBL-producing *E. coli* is not restricted to livestock only, their occurrence in zoo animals, companion animals, and wild animals has been reported [37,42-54].

The past decade witnessed an unprecedented rise in the spread of antimicrobial resistant bacterial pathogens in humans and animals worldwide [19,42,43,55,56]. The most interesting scenario, however, is the occurrence of CTX-M group of enzymes among apparently healthy individuals without a recent history of hospitalization and the evolution of new classes of CTX-M type of ESBL [1,57-59]. Based on the similarities in the amino acid sequence of these enzymes, there are more than 80 heterogeneous groups of ESBL that are categorized into five distinct groups (CTX-M-1, M-2, M-8, M-9, and M-25), these groups shared more than 90% similarity in their amino acid sequence [59,60]. These ESBL genes are commonly found in *E. coli* strain isolated from humans and animals, possibly due to plasmid transfer or spread of unique clonal lineages [4]. ESBL belonging to the CTX-M-9 family is the most predominant ESBL genes circulating among *E. coli* strains in Asia [61]. This was partly due to the emergence of ESBL and AmpC beta-lactamase-producing *E. coli*. Before the early to late 1990s, a substantial proportion of ESBL associated with humans was the narrow-spectrum beta-lactamases (TEM-1, TEM-2, and the SHV-1) [49,62]. At present, the occurrence of AmpC-beta-lactamase and ESBL is now a global phenomenon, and the CTX-M type ESBL is now the most commonly identified enzymes worldwide [1,60].

The occurrence of ESBL and AmpC- producing *E. coli* from humans, food animals, and companion animals has been reported. Interestingly, a few studies have also reported the isolation of bacterial strains from livestock and companion animals that shared similar clonal lineage as those commonly isolated from humans [24,63,64], indicating that animals are serving as potentials reservoirs of infection to humans. The most commonly associated ESBL genotypes in animal encode for the different CTX-M group of enzymes such as the $bla_{\text{SHV-12}}$ and the $bla_{\text{TEM-52}}$ in addition to SHV and TEM [42,55,63]. $bla_{\text{CMY-2}}$ is the most commonly identified AmpC beta-lactamases [43,63,64]. Table-1 gives a detailed worldwide occurrence of ESBL genes from animals, humans, and the environment as well as the risk factors of their occurrence in humans.

Risk Factors of ESBL-Producing *E. coli* from Livestock and the Environment

A wide range of farm management practice such as exposure of animal to contaminated feed and water, and absence of water acidification in poultry production, importation of parent stock or day old grand chickens, contamination of plant food sources and with manure serves as reservoirs of ESBL/AmpC-bacteria and may promote the entry and transmission of ESBL/AmpC-producing *Enterobacteriaceae* [65-67]. Establishing the true risk factors that may facilitate of ESBL/AmpC-producing *Enterobacteriaceae* is cumbersome and characterized by an absence or paucity of reliable data. To fully understand the factors that may encourage the occurrence of these pathogens, there is a need for more research to understand the key driving forces that have the potentials to facilitate rapid dissemination of the bacteria across regions, countries, and continents [65].

ESBL/AmpC-producing *E. coli* and other members of the *Enterobacteriaceae* are increasingly emerging as a public health problem worldwide [17,68]. The ESBL are plasmid coded enzymes that inactivate beta-lactams antimicrobial agents by hydrolyzing their beta-lactam ring. The ESBL genes are vertically transferred to daughter cells during cell division. However, horizontal transfer of these genes to other bacteria through conjugation, transduction, and transformation has been reported to occur [69]. On the other hand, AmpC is intrinsic beta-lactamase enzymes that are located on the chromosome of a wide range of Gram-negative bacteria. They confer resistance to penicillin, first, second, and third generation cephalosporins, cephamycin, and β-lactam/inhibitor combinations except for carbapenem and fourth generation cephalosporins. Interestingly, many AmpC enzymes are now captured (“escaped”) on the plasmids (“plasmidic” AmpC or termed “acquired”). These enzymes belong to six phylogenetic groups and CMY-2 is the most commonly identified [65].

The occurrence of these pathogens is increasingly being reported from food sources worldwide, and humans can come down with infection through the food chain [70,71]. ESBL/AmpC-producing *E. coli* have been described in natural environments such as water bodies [72]. Contamination of the environment with ESBL/AmpC-producing *E. coli* can occur through animal and human feces, agricultural and industrial waste. These serve as an important dissemination route and the subsequent emergence of highly pathogenic resistant bacteria [72-74]. The development of AMR is mostly associated with a sustained and indiscriminate use of antimicrobials either for treatment or prophylactic purposes in humans and animals. This has led to the emergence of highly resistant bacteria and increased dissemination of resistance determinants. Increased shedding of multiple drug-resistant *E. coli* strains has been reported in calves and

Table-1: Occurrence and risk factors of ESBL/AmpC-producing *E. coli* from livestock, pets, and the environment.

Location	Sources	Bacteria	Occurrence (%)	ESBL/AmpC type enzyme detected	Risk factors	Reference
Germany	Surrounding air	*E. coli*	3/40 (7.5)	bla_{CTX-M}	Surrounding air, feces. Boot swabs	[108]
	Slurry	*E. coli*	12/14 (86)			
	Boot swabs	*E. coli*	23/80 (28.8)			
Germany	Dairy farms	*E. coli*	82/866 farms (9.5)	bla_{CTX-M}	Consumption of raw milk and farm environment	[109]
Germany	Diseased animals cows and pigs	*E. coli*	419/6849	$bla_{CTX-M-1}$, $bla_{CTX-M-15}$, $bla_{CTX-M-14}$, bla_{TEM-52}, $bla_{CTX-M-3}$, bla_{SHV-12}, $bla_{CTX-M-2}$	Feces, raw milk	[11]
France	Slaughtered veal calves	*E. coli*	144/491 (29.4)	bla_{CTX-M}	Contaminated slaughter house/ abattoir	[110]
Netherlands	Recreational waters	*E. coli*	144 (62)	CTX-M-15, CTX-M-1	Recreational waters	[111]
United Kingdom	Dairy farms	*E. coli*	10/17 farms (58.8)	CTX-M-15, CTX-M-55, CTX-M-1, CTX-M-32, CTX-M-14, CTX-M-14b, CTX-M-27	Raw or unpasteurized milk	[112]
Germany	Bovine mastitis	*E. coli*	16 (94%)	CTX-M-1, CTX-M-2, CTX-M-14, CTX-M-15	Raw or unpasteurized	[113]
Germany	Sick horses	*E. coli*	320/341 (94)	$bla_{CTX-M-1}$	Health-care setting	[114]
Germany	Conference participants	*E. coli*	8/231 (3.5)	bla_{SHV-12}	Contact with pets, travel to Greece, Travel to Africa	[79]
Netherlands	Human fecal sample	*E. coli*	109/2432 (4.5)	$bla_{CTX-M-15}$, $bla_{CTX-M-14}$, $bla_{CTX-M-17}$, $bla_{CTX-M-1}$	Contact with cows, use of proton-pump inhibitors, 1 km proximity to mink farms	[115]
Spain	Wastewater	*E. coli*	241/279 (86.5)	bla_{CTX-M}, bla_{TEM}, bla_{SHV}	Waste untreated water	[116]
United Kingdom	Raw meat (397) fruits and vegetables (400)	*E. coli*	Beef (1.9), pork (2.5), chicken (65.4)	$bla_{CTX-M-1}$	Raw chicken, beef, pork, fruit, and vegetables	[117]
Mexico	Healthy dogs	*E. coli*	3/53 (6)	$bla_{CTX-M-15}$, bla_{SHV-2}	Contact with dogs	[118]
Egypt	Chicken meat	*E. coli*	19/55	bla_{TEM}, bla_{SHV}	Raw chicken meat	[119]
Nigeria	Untreated wastewater/ groundwater	*E. coli*	114/143 (79.7)	bla_{SHV}, *bla*CTX-M-15, bla_{TEM}	Untreated water	[120]
Nigeria	Animals and environment	*E. coli*	49/457	$bla_{CTX-M-15}$	Extensive/ free range management system	[121]
Zambia	Chicken meat	*E. coli*	77/384 (20.1)	bla_{SHV}, bla_{CTX-M}, bla_{TEM}	Raw or uncooked chicken meat	[122]
Turkey	Mastitic milk	*E. coli*	3/3 (100)	$bla_{CTX-M-15}$, bla_{TEM-1}	Raw milk	[123]
India	Natural aquatic environment	*E. coli*	61/261	bla_{TEM}, bla_{CTX-M}, AmpC	Aquatic environment	[124]
Thailand	Natural water environment	*E. coli*	68	$bla_{CTX-M-1}$, $bla_{CTX-M-9}$, AmpC	Natural water	[125]
Turkey	Raw milk, Raw chicken meat, and cow milk cheese	*E. coli*	200/250 (80)	bla_{TEM}, bla_{CTX-M}, bla_{SHV}	Food of animal origin	[126]
Thailand	Pig and chicken carcass	*E. coli*	16/667	$bla_{CTX-M-15}$, bla_{TEM-1}, bla_{CMY-2}	Raw pork and poultry meat	[127]
France	Laboratory surfaces	*E. coli* ST744	36/1398	$bla_{CTX-M-55}$	Environmental surfaces	[128]
Czech Republic	Raw cow milk	*E. coli*	2/243 (0.7)	bla_{CTX-M}	Raw milk	[129]
Czech Republic	Sympatric black-headed seagull water surfaces	*E. coli*	7/216 (3)	$bla_{CTX-M-1}$, $bla_{CTX-M-15}$, bla_{SHV-2}, bla_{SHV-12}	Contamination of water surfaces	[130]

(Contd...)

Table-1: *(Continued)*

Location	Sources	Bacteria	Occurrence (%)	ESBL/AmpC type enzyme detected	Risk factors	Reference
Thailand	Poultry meat	*E. coli* ST131	143/250	$bla_{CTX-M-1}$, bla_{TEM-16}, bla_{SHV-29}, bla_{SHV-12}	Poultry meat	[131]
China	Chicken	*E. coli*	31/51	bla_{TEM}, bla_{CTX-M} and bla_{SHV}	Chicken meat	[41]
Spain	Poultry, pig, and rabbit	*E. coli*	97/360	TEM-52, SHV-12, CTX-M-1, CTXM-9, CTX-M-12, CTX-M-14, CTX-M-32, CTX-M-14+1, SHV-5+CTX-M-9, SHV-2+CTX-M-1, CTX-M-12, CMY-12	Poultry meat, pork, and rabbit	[97]
Denmark	Pigs, pig farmers, and their family members	*E. coli*	79% in pigs farm with consumption of cephalosporins, 20% in pig farms without cephalosporin	$bla_{CTX-M-1}$, $bla_{CTX-M-14}$, bla_{SHV-12}	Consumption of third generation of cephalosporins, contact with pets	[52]
Iran	Calves and dairy cows	*E. coli*	2/205 (0.97)	-	Raw milk and contact with diarrheic calves	[132]
Indonesia	Cow milk	*E. coli*	4/129 (3.1)	$bla_{CTX-M-55}$, $bla_{CTX-M-15}$	Unpasteurized or raw cow milk	[133]
UK	Pig cecal sample	*E. coli*	637 (23.4)	bla_{CTX-12}, bla_{SHV-12}	Pork	[134]
Ireland	Food producing animals and healthy humans	*E. coli*	87	-	Food producing animals	[135]
Portugal	Dog	*E. coli*	1	CTX-M-1	Contact with pets	[136]
Portugal	Cattle, poultry	*E. coli*	31	CTX-M-1	Food producing animals	[97,137]
Hong Kong	Pig	*E. coli*	61	CTX-M-3, CTX-M-13, CTX-M-15	Pork	[7]
Japan	Cattle and broiler	*E. coli*	13	CTX-M-2	Beef and chicken meat	[138,139]
UK	Cattle	*E. coli*	114	CTX-M-14	Beef	[71,140]
Italy	Pets	*E. coli*	23	CTX-M-1, SHV-12	Contact with pets	[141]
Nigeria	Chickens	*E. coli*	21 (32.0)	-	Contact with poultry feces	[142]

E. coli=*Escherichia coli*, ESBL=Extended-spectrum beta-lactamase, AmpC=Ampicillin Class C

other livestock [75-78], suggesting that AMR might not only be restricted to the use of antimicrobial agents for treatments but also that other important factors might have played a role.

While many studies have reported human to human contact, travel, hospital admission as important sources of contamination for humans, livestock and pets have also been reported to serve as potential risk factors of spreading ESBL-producing *E. coli* to humans [79-83]. The isolation of multiple drug-resistant *E. coli* from calf feces has been associated with age, and increased shedding of these pathogens seems to occur during milk feeding [84,85]. Several studies have reported the occurrence of peak resistance rate in calves between the ages of 2 and 4 weeks old; however, a gradual decline was observed afterward [76,84,85], suggesting that the peak resistance might be the result of exposure to antimicrobials through the consumption of milk or colostrum from cows treated with antimicrobial agents. The occurrence of highly resistant *E. coli* strains was reported in calves fed none-pasteurized milk than those fed on bulk milk tank [86,87]. Other studies conducted by Xu *et al*. [88] and Brunton *et al*. [89] reported the occurrence of high ESBL-producing *E. coli* in farms that fed calves with milk containing antimicrobial residue than in farms that do not use such milk. The outcome of these studies showed that treatment of cows with antimicrobial agents during lactation can significantly increase the shedding of highly resistance ESBL-producing *E. coli* by calves.

Several studies have also reported the occurrence of ESBL/AmpC in conventionally farmed dairy, veal, and beef cattle to range from 35.4% to 86.7% (herd level) and 1 to 32.8% (animal level) [80,90-95]. On the other hand, Santman-Berends *et al*. [84] reported the occurrence of 12/90 (13%) ESBL/AmpC bacteria in slurry samples collected from an organic dairy farm. The authors also found no association between the use of third and fourth generation cephalosporins and the ESBL/AmpC status of the herd. However, location of pig farms within 2 km radius, providing milk replacers to the female calves after ingestion of colostrum and treatment of mastitis were considered as likely risk factors associated with higher chances of being ESBL/AmpC positive. A strong correlation between the withdrawal of ceftiofur as a prophylactic agent in hatcheries and reduction in the occurrence

of AmpC-producing ceftiofur-resistant *E. coli* and ceftiofur-resistant *Salmonella* Heidelberg from retail poultry and humans across different regions of Canada was also reported [65,96]. In Switzerland, the occurrence of ESBL-producing *E. coli* in pigs after sampling 334 fecal samples from pigs was 15.3%. Blanc *et al*. [97] and Mesa *et al*. [98] reported the occurrence of ESBL-producing *Enterobacteriaceae* in 36.5% out of 131 and 8/10 fecal samples collected from fattening pigs and sampled pig farms, respectively, in Spain. Machado *et al*. [99] and Laube *et al*. [100] also reported the occurrence of 5.7% and 43.8% ESBL-producing *Enterobacteriaceae* from 35 healthy pigs and 16 pig farm holdings in Portugal and Germany, respectively. The occurrence was, however, lower in Japan where Hiroi *et al*. [101] reported the occurrence of 3% ESBL-producing *Enterobacteriaceae* from rectal swabs of 33 pigs in a slaughterhouse. The isolation of these pathogens from fecal sample indicated the role of fecal contamination of food and food animal product as an important route of spread of ESBL bacteria to humans. This also showed that the transmission between livestock and their environment is crucial to the occurrence of ESBL/AmpC-producing *E. coli* and subsequently spreading to humans.

Since ESBL-producing *E. coli* show a high level of resistance to a large compendium of beta-lactam antimicrobial agent including the third generation of cephalosporin, coresistance selection is likely to occur with other classes of antimicrobial agents which included aminoglycosides, fluoroquinolones, tetracycline, and sulfonamide that resulted to the use of last line of antibiotics for the treatment of ESBL-producing *E. coli* infection in humans. These selective pressures mounted due to indiscriminate use of antimicrobial agents favors the persistence and carriage of ESBL producing *E. coli* in humans both in the hospital and the community as well as livestock and pets. The use of antimicrobial agents such as third and fourth generation cephalosporins is critical to the development of resistance, and it is considered as one of the major factors contributing to the occurrence of ESBL-producing *E. coli* in pig and dairy. Storage of slurry in a pit, infrequent cleaning of calf feeding equipment and environment, operating an open herd policy, extensive international trade of animals, and the presence of fish ponds in poultry farms were considered major risk factors of occurrence of ESBL-producing *E. coli* in livestock and other animals [46,90,102-107]. Table-1 [7,11,41,52,71,79,97,108-142] gives a detailed description of the risk factors that may contribute to the occurrence of ESBL/AmpC-producing *E. coli* in humans.

Conclusion

AMR is a global human and animal health problem that has posed a significant challenge. The emergence of ESBL/AmpC-producing *E. coli* in humans through the food chain showed that dynamism of resistance determinants requires a multi-sectoral and interdisciplinary approach. Due to the expansion of the risk factors that facilitates the spread and maintenance of these pathogens.

Authors' Contributions

AAB and PAM conceptualized this review article and wrote the first draft. IDK proof-read the manuscript, MDG and SMJ helped in the literature search. All authors read and approved the final draft of this manuscript.

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Competing Interests

The authors declare that they have no competing interests.

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